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Factors Affecting the Yield of Kraut Cabbage in Ohio as Determined by a Survey and Cooperative Field Tests

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FACTORS AFFECTING THE YIELD OF KRAUT CABBAGE IN OHIO AS DETERMINED BY A SURVEY AND COOPERATIVE FIELD TESTS

CECIL WADLEIGH, H. D. BROWN, AND ROBERT YOUNG

INTRODUCTION

Not so very many years ago, the kraut industry of Ohio was seriously threatened by cabbage yellows (*Fusarium conglutinans* Wollenw.). The situation which this pathogene brought about was ameliorated by the development of "yellows-resistant" strains of the more prominent varieties of cabbage. Even with the advent of a successful means of controlling this disease, Ohio cabbage growers have experienced low yields during the past several seasons. This is of vital concern to the kraut packers because they have, through long experience and countless observations, correlated good quality kraut with a high yield of cabbage. The National Kraut Packers' Association considered it advisable, therefore, to initiate a study of the factors affecting the yield of late cabbage under Ohio conditions.

The present study is in part a repetition of an investigation (25) made during the season of 1930. However, cabbage yields were very low that year as a result of drouth, and it seemed advisable to repeat the work with some modifications during the season of 1931.

METHODS OF PROCEDURE

During the summer of 1931, approximately 350 cabbage fields in northern Ohio were visited. Most of these fields were located in Sandusky, Erie, and Mercer Counties. Each owner was personally interviewed for data concerning the previous crop grown on the field; kind, amount, and method of fertilization; date of plowing the field for cabbage; method of planting cabbage in the field, and, if transplanted, the time and procedure of transplanting; varieties used; and the number and depth of the cultivations. The data for the soil type and color, condition of soil at transplanting time, planting distance, percentage of perfect stand, insect and disease injury, and weediness were secured by a personal inspection of the fields. Three or more soil samples (depending upon the size of the field) were secured from each field. From these samples, the approximate nitrate nitrogen content, available phosphorus content, and acidity in pH of the soil in the field were obtained.

Nitrate nitrogen was determined by the diphenylamine method as devised by Morgan (14). The available phosphorus was determined according to the procedure outlined by Bray (1). The La Motte "Soil Teskit" was used for the soil acidity determinations.

The yield per acre which each grower secured was calculated from the acreage he devoted to cabbage and the amount of cabbage he delivered to the kraut plant. Inasmuch as every field considered was under contract, the entire crop was, with the exception of a few instances, delivered to the kraut plant. In case it was known that a grower ignored his contract and delivered a portion or all of his cabbage elsewhere, the survey sheet containing the data for his field was discarded.

The average yields and the probable errors and odds are shown in Tables 1 to 14, inclusive. The significance of the differences in yields was determined by the method of Wood (23). Although the results of most of the survey data agree with records secured by Young in 1930, it nevertheless should be remembered that the data presented are for the fairly dry season of 1931. It is possible that some different results might be secured under different environmental conditions. Even though the number of individual records in the survey is high, the probable errors low, and the odds significant, there is still a possibility that correlated factors may have influenced the data to a greater extent than the odds indicate. The probable error rather than the standard error has been used in all instances.

Seven series of fertilizer test plots were carried on in different localities in northern Ohio. Two of these were located at Fremont and one each at Sandusky, Clyde, Erlin, Green Springs, and Celina. Each series consisted of 10 plots receiving various fertilizer treatments, excepting at Celina where the series contained 14 plots. Each plot was one-twentieth of an acre in area. Cabbage plants were set 18 inches apart, in rows 30 inches apart, in each plot. The fertilizer was applied before setting the plants and was disked into the soil. Each plot was separated from the adjacent ones by two guard rows.

The yields resulting from similar treatments in the different localities were averaged and the significance of the difference between any two given treatments was determined by Love's (11) modification of "Student's" method.

Eight different lots of sauerkraut were made from samples of cabbage secured from as many different fields. Each lot of cabbage was selected because of its specific physiological status resulting from the nutritional conditions obtaining in the field. The recommendations of LeFevre (10) were followed in making the sauerkraut and in testing for salinity, acidity, and quality.

Sugar determinations were made on these eight samples of cabbage according to the Shaffer and Hartmann (16) method. The sample was prepared according to the procedure outlined by Burrell (2).

PRESENTATION OF DATA

EDAPHIC

The type of soil in each given field in which cabbage was growing was classified as to whether it was a sand, sandy loam, loam, or a heavy loam.

Tables 1 and 2 indicate that the superiority of sandy soils over heavy loam soils for kraut cabbage production is quite significant. Young's (25) results point toward the same conclusion. Since Jones (6), Mack (13), and Thompson (18) all state that the heavy soils produce the largest crops, an explanation of the accompanying figures is in order. The sandy soils were all of lacustrine origin and many of them were very high in organic matter (10 to 15 per cent). Free water was found at a depth of 5 to 8 feet in excavations made during late summer on sandy soils which were being used for cabbage production.

Many of the heavy loams belonged to the Miami series. This soil is not very high in organic matter, and excavations to the depth of 8 feet failed to indicate the presence of a water table. Moisture determinations on various soil types indicated that the relative amount of water available to plants was decidedly greater in the sandy soils.

TABLE 1.—Effects of Soil Type on the Yield of Cabbage*

No. of fields	Soil type and yields in tons per acre	Differences in yields, their probable errors, and odds†			
		Sandy loam	Sand	Loam	Heavy loam
36	Sandy loam 9.32±0.37		0.23±0.41 (.....)	1.08±0.49 (7 to 1)	1.53±0.45 (35 to 1)
172	Sand 9.09±0.15	0.23±0.41 (.....)		0.85±0.33 (10 to 1)	1.30±0.27 (1000 to 1)
41	Loam 8.42±0.30	1.08±0.49 (7 to 1)	0.85±0.33 (10 to 1)		0.45±0.37 (1 to 1)
57	Heavy loam 7.79±0.22	1.53±0.45 (35 to 1)	1.30±0.27 (1000 to 1)	0.45±0.37 (1 to 1)	

*The probable error rather than the standard error has been used throughout this paper.
†A difference must be about three times its probable error to be considered significant. The odds are against such differences occurring by chance under uniform conditions. These statements apply to Tables 1 to 14, inclusive.

The precipitation for June 1931 was about normal for northern Ohio. This is the month during which the cabbage is transplanted to the field. Abundant rainfall on a sandy soil would percolate down to the lower strata; whereas on a heavy soil the moisture would tend to be held near the surface, due to the retentive nature of such a soil, or lost by surface run-off. It must also be remembered that the extreme conditions of drouth of the previous year had excessively lowered the moisture content of even the heaviest soils to a considerable depth. If the June weather conditions are taken into account, it is questionable whether the cabbage root penetration on the heavy soil was as extensive as in the sandy soils. Thus, the plants growing on sandy soils were probably better equipped to withstand the extremely dry, hot weather of July 1931, and, in addition, it is very probable that the spring rains penetrated deeper into the sandy soils.

Soil color.—The soils were also classified as to color. They were grouped as to whether they were black, dark gray or dark brown, medium gray or medium brown, or light gray or yellow in the moist state.

TABLE 2.—Effects of Soil Color on the Yield of Cabbage

No. of fields	Soil type and yields in tons per acre	Differences in yields, their probable errors, and odds			
		Black	Dark	Medium	Light
51	Black 9.47±0.27		0.48±0.31 (2 to 1)	1.17±0.42 (10 to 1)	2.43±0.36 (1350 to 1)
185	Dark 8.99±0.14	0.48±0.31 (2 to 1)		0.69±0.35 (4 to 1)	1.95±0.29 (1350 to 1)
43	Medium 8.30±0.32	1.17±0.42 (10 to 1)	0.69±0.35 (4 to 1)		1.26±0.40 (30 to 1)
27	Light 7.04±0.25	2.43±0.36 (1350 to 1)	1.95±0.29 (1350 to 1)	1.26±0.40 (30 to 1)	

The odds in favor of the darker colored soils when compared with those for the lighter ones indicate beyond doubt the superiority of the former. The figures bear out the relationship mentioned by Worthen (24) in respect to increased productivity with a darker colored soil. The data are also in accord with the statements by Mack (13) and Fite (5); namely, that cabbage does best on soils containing appreciable quantities of organic matter.

Soil acidity.—The survey data were classified into three groups according to the degree of soil acidity of the cabbage fields. All soils testing pH 7.0 or above were placed in one class, those testing between 6.0 and 7.0 in a second, and those giving a test below pH 6.0 in a third grouping.

TABLE 3.—Effects of Soil Acidity on the Yield of Cabbage

No. of fields	Soil reaction and yields in tons per acre	Differences in yields, their probable errors, and odds		
		pH 7 or higher	pH 6.0 to 6.9	pH 5.9 or lower
70	pH 7 or higher 9.33±0.28		0.70±0.31 (10 to 1)	0.91±0.33 (20 to 1)
188	pH 6.0 to 6.9 8.63±0.14	0.70±0.31 (10 to 1)		0.21±0.25 (.....)
48	pH 5.9 or lower 8.42±0.21	0.91±0.33 (20 to 1)	0.21±0.25 (.....)	

The odds secured do not indicate a significant difference in the yield of cabbage grown in fields with a difference in soil acidity. Nevertheless, they do indicate a tendency towards increasing yield with decreasing acidity.

Soil nitrates.—The yields of cabbage in fields testing less than 6 parts per million of soil nitrates [according to the diphenylamine test (14)] were grouped. Those fields testing 7 to 15 parts per million were grouped, and those giving a test of over 20 parts per million were placed in a third group. Tests were made during July.

TABLE 4.—Effects of Soil Nitrate Content on the Yield of Cabbage

No. of fields	Nitrates in p.p.m. and yields in tons per acre	Differences in yields, their probable errors, and odds		
		20 or more p.p.m.	7 to 15 p.p.m.	0 to 5 p.p.m.
146	20 or more p.p.m. 8.95±0.18		0.17±0.24 (.....)	0.92±0.38 (10 to 1)
129	7 to 15 p.p.m. 8.78±0.16	0.17±0.24 (.....)		0.75±0.23 (9 to 2)
31	0 to 5 p.p.m. 8.03±0.34	0.92±0.38 (10 to 1)	0.75±0.38 (9 to 2)	

It is apparent from Tables 1 through 4 that the differences in yield accompanying differences in soil nitrate content, as determined by the diphenylamine test, are not quite significant. The odds do indicate, however, a tendency for the yields of cabbage on fields with the higher soil nitrate content to be superior to those from fields having a low content of soil nitrates.

Available phosphorus.—The available phosphorus in the cabbage field, as determined by Bray's method, was classified as to whether it was high, medium, or low. The yields of the respective fields were grouped accordingly.

The data were characterized by a lack of significant differences. Since it is known that cabbage is highly responsive to phosphorus, it is believed that the method used in testing the soil for available phosphate was not entirely

TABLE 5.—Effects of Preceding Crops on the Yield of Cabbage

No. of fields	Preceding crop and yields in tons per acre	Differences in yields, their probable errors, and odds								
		Clover	Potatoes	Corn	Cabbage	Alfalfa	Wheat	Truck	Oats	Grass sod
34	Clover 9.86±0.22		0.40±0.38 (1 to 1)	0.64±0.31 (9 to 2)	1.04±0.53 (4 to 1)	1.06±0.38 (15 to 1)	1.52±0.41 (35 to 1)	2.27±0.48 (500 to 1)	2.30±0.40 (1350 to 1)	2.43±0.37 (1350 to 1)
38	Potatoes 9.46±0.31	0.40±0.38 (1 to 1)		0.24±0.38 (.....)	0.64±0.57 (1 to 1)	0.66±0.44 (2 to 1)	1.12±0.47 (10 to 1)	1.87±0.53 (35 to 1)	1.90±0.45 (150 to 1)	2.03±0.43 (500 to 1)
95	Corn 9.22±0.22	0.64±0.31 (9 to 2)	0.24±0.38 (.....)		0.40±0.53 (.....)	0.42±0.38 (1 to 1)	0.88±0.41 (5 to 1)	1.63±0.48 (35 to 1)	1.66±0 40 (140 to 1)	1.79±0.37 (800 to 1)
23	Cabbage 8.82±0.48	1.04±0.53 (4 to 1)	0.64±0.57 (1 to 1)	0.40±0.53 (.....)		0.02±0.57 (.....)	0.48±0.59 (.....)	1.23±0.64 (4 to 1)	1.26±0.58 (7 to 1)	1.39±0.57 (8 to 1)
10	Alfalfa 8.80±0.31	1.06±0.38 (15 to 1)	0.66±0.44 (2 to 1)	0.42±0.38 (1 to 1)	0.02±0.57 (.....)		0.46±0.47 (1 to 1)	1.21±0.53 (7 to 1)	1.24±0.45 (15 to 1)	1.37±0.43 (30 to 1)
34	Wheat 8.34±0.35	1.52±0.41 (35 to 1)	1.12±0.47 (10 to 1)	0.88±0.41 (5 to 1)	0.48±0.59 (.....)	0.46±0.47 (1 to 1)		0.75±0.55 (2 to 1)	0.78±0 48 (2 to 1)	0.91±0.46 (9 to 2)
17	Truck 7.59±0.43	2.27±0.48 (500 to 1)	1.87±0.53 (35 to 1)	1.63±0.48 (35 to 1)	1.23±0.64 (4 to 1)	1.21±0.53 (7 to 1)	0.75±0.55 (2 to 1)		0.03±0.54 (.....)	0.16±0.52 (.....)
23	Oats 7.56±0.33	2.30±0.40 (1350 to 1)	1.90±0.45 (150 to 1)	1.66±0.40 (140 to 1)	1.26±0.58 (7 to 1)	1.24±0.45 (15 to 1)	0.78±0.48 (2 to 1)	0.03±0.54 (.....)		0.13±0.45 (.....)
32	Grass sod 7.43±0.30	2.43±0.37 (1350 to 1)	2.03±0.43 (500 to 1)	1.79±0.37 (800 to 1)	1.39±0.57 (8 to 1)	1.37±0.43 (30 to 1)	0.91±0.46 (9 to 2)	0.16±0.52 (.....)	0.13±0.45 (.....)	

reliable. Nevertheless, it was observed in instances where no color whatsoever was developed by the test that the cabbage presented a decidedly stunted appearance.

Preceding crop.—The cabbage fields were grouped as to the preceding crop grown in the field, and the average yield of cabbage for each group was determined.

Cabbage following clover and cultivated crops gave the most profitable yield. This is explained in part by the fact that the cultivated crops, such as potatoes, corn, and cabbage, usually receive much more fertilizer than is applied to hay, oats, or wheat. The season of 1930 was not conducive to the intake of fertilizer by a crop; thus, the ordinary residual effect of fertilization was greatly enhanced. Furthermore, crops such as oats and wheat leave considerable stubble which, during decomposition, deprives the soil of nitrogen.

Soil condition at transplanting time.—Notes were taken as to whether the soil in the cabbage fields was in a good, fair, or poor condition at transplanting time. This classification was based upon the extent to which the structure of the soil was flocculated or granulated as a result of the tillage procedure practiced.

TABLE 6.—Effects of Soil Condition at Transplanting Time on the Yield of Cabbage

No. of fields	Soil condition and yield in tons per acre	Differences in yield, their probable errors, and odds		
		Good	Fair	Poor
242	Good..... 9.22±0.16.....		1.85±0.33 (1350 to 1)	3.02±0.47 (1350 to 1)
53	Fair..... 7.37±0.29.....	1.85±0.33 (1350 to 1)		1.17±0.48 (10 to 1)
11	Poor..... 6.20±0.44.....	3.02±0.47 (1350 to 1)	1.17±0.48 (10 to 1)	

The results are entirely in accordance with the writings of other investigators.

The advantage of having the soil in a good structural condition at transplanting time is very marked. In all the fields surveyed, there was not one sandy or sandy loam soil in a poor condition. It is of interest to note that eight of the 11 fields which were in a poor condition at transplanting time were plowed during the latter half of April. The other three were plowed during May. The cause of the adverse structural state in all of these soils was the tilling of them while too wet. This deflocculated the colloidal particles and resulted in the formation of clods. A cloddy soil is not only difficult for plant roots to permeate, but it is also lower in available moisture and plant nutrients. A combination of such factors would be highly detrimental to the growth of cabbage, especially under the climatic conditions existing during July 1931.

CULTURAL

Plowing date.—The fields were classified as to whether they were plowed before April, during April, or after April. These differences in plowing dates were not accompanied by significant differences in yields. Although early plowing is usually recommended, this practice does not have as great a bene-

ficial effect on a sandy soil as on one of heavy texture. Since the majority of the soils considered were more or less sandy, the expected beneficial effects of early plowing were obscured.

Method of planting cabbage in field.—In two of the districts, Liberty Center and the northern part of the Fremont, Ohio, District, some of the growers make a practice of sowing the cabbage seed thinly in rows in the field and blocking out surplus plants later. The average yield of the fields on which this practice was followed was compared with the average yield of the fields into which the plants had been transplanted. The data considered were confined to the two districts mentioned above.

TABLE 7.—Effect of Method of Planting on the Yield of Cabbage

No. of fields	Method of planting and yield in tons per acre	Differences in yield, their probable errors, and odds	
		Transplanted	Blocked
29	Transplanted 9.17±0.54		1.17±0.62 (4 to 1)
39	Blocked 8.00±0.32	1.17±0.62 (4 to 1)	

The small number of observations lessened the significance of the data. Nevertheless, the odds, small though they were, were in favor of the field in which the cabbage was transplanted. Presumably the plants that were transplanted had to undergo a setback which those that were blocked did not receive. This would make it possible for the blocked cabbage to mature earlier. Cabbage, being a cool-season crop, could certainly not develop to its best if it were maturing during the very hot weather of the latter part of July and the early part of August 1931.

Date of transplanting.—The plants which were transplanted before June 16 were segregated from those which were transplanted later than this date, and the average yield for each group calculated.

TABLE 8.—Effect of Date of Transplanting on the Yield of Cabbage

No. of fields	Date of transplanting and yield in tons per acre	Differences in yield, their probable errors, and odds	
		Before June 16	After June 15
155	Before June 16 9.12±0.16		0.79±0.23 (35 to 1)
111	After June 15 8.33±0.17	0.79±0.23 (35 to 1)	

It is quite evident that the earlier transplanted cabbage produced the better yields. Not only was the early part of June 1931 much cooler than the latter part, but, also, there was more precipitation during the early part of the month than during the latter part. To a plant which has just been transplanted, conditions favoring high transpiration are just as detrimental as those which make for an insufficient supply of water. It would seem, therefore, that it was more difficult to secure a good stand of plants by transplanting during the latter part of the month.

Planting distance.—When the fields were classified as to various planting distances used, few significant differences were secured. The data did signify, however, that setting the plants too far apart in widely spaced rows reduced yield. Also, setting the plants too close together in narrowly spaced rows reduced the yield. A spacing of 30 inches by 28 inches resulted in the highest average yield.

Hand versus machine transplanting.—A comparison of the methods (hand versus machine) of transplanting the plants to the field showed that this factor did not influence the yield.

Use of water in the transplanting machine.—The yields of cabbage plants transplanted at different dates were compared to determine whether or not the use of water in the transplanting machine was advisable.

TABLE 9.—Effects of the Use of Water in Transplanter

No. of fields	Use of water and yield in tons per acre	Date	Differences in yields, their probable errors, and odds	
			Water used	Water not used
17	Water used 8.53±0.40	June 10		1.43±0.61 (7 to 1)
26	Water not used 9.96±0.48		1.43±0.61 (7 to 1)	
33	Water used 9.51±0.23	June 15		0.62±0.85 (.....)
15	Water not used 10.13±0.82		0.62±0.85 (.....)	
34	Water used 9.47±0.30	June 20		1.77±0.62 (17 to 1)
10	Water not used 7.70±0.54		1.77±0.62 (17 to 1)	

The inconsistency of the data on the use of water in the transplanter would seem to obscure their significance. The odds tend to indicate that the use of water in the machine was a detriment to the cabbage transplanted on June 10, that it made no difference whether or not water was used on June 15, and that the use of water on June 20 was quite beneficial. There had been a rather heavy rain just previous to June 10, and the mean temperature for that day was moderately low. Conditions were very near optimum for transplanting. It is possible that the addition of more water to the soil, which was already nearly saturated, might have tended to "puddle" it. On June 15, the mean temperature was somewhat higher, and, although the soil was fairly moist as a result of a light shower, there had been a tendency for the soil to dry out somewhat. Conditions were, nevertheless, sufficiently favorable for transplanting so that the use of water had no advantage. On June 20, the mean temperature had become quite high, and no appreciable precipitation had occurred for about 10 days. Conditions were not very favorable for transplanting; hence, as the data indicate, it was advantageous to use water in the transplanting machine at this time. It is also of some significance that the percentage of fields in which cabbage was transplanted with the use of water increases from June 10 to June 20.

Variety.—Most farmers grow more than one variety of cabbage in their fields, making it impossible to use the records of such fields in comparing the influence of variety on the yield. However, some growers plant only one variety on their fields. Data given in Table 10 were taken from the records of such fields.

Fig. 1.—At transplanting time the plants in the center row shown in the picture received no water; the plants in the rest of the field did. Soil was dry at time of transplanting

The most striking thing in these results is the decided inferiority of the Commercial Glory. This was the only variety which was not "yellows" resistant, and its susceptibility accounted for the lower yields whenever this variety was grown on soil infected with cabbage yellows. Jones *et al.* (8) present evidence to show that climatic conditions such as existed during July 1931 are very favorable to the development of Fusarium. Only varieties which were resistant to the pathogene could produce profitable yields.

TABLE 10.—Effects of Variety Upon the Yield of Cabbage

No. of fields	Variety used and yields in tons per acre	Differences in yields, their probable errors, and odds			
		All Seasons	Globe Glory	All Head	Commercial Glory
74	All Seasons 9.16±0.19		0.06±0.61 (.....)	0.88±0.28 (25 to 1)	3.16±0.51 (1350 to 1)
20	Globe Glory 9.10±0.58	0.06±0.61 (.....)		0.82±0.62 (2 to 1)	3.10±0.75 (150 to 1)
14	All Head 8.28±0.21	0.88±0.28 (25 to 1)	0.82±0.62 (2 to 1)		2.28±0.51 (500 to 1)
17	Commercial Glory 6.00±0.47	3.16±0.51 (1350 to 1)	3.10±0.75 (150 to 1)	2.28±0.51 (500 to 1)	

Number of cultivations.—The fields were classified as to whether they were cultivated three times or less, four to six times, or more than six times.

Many growers make it a practice to cultivate their cabbage every week regardless of weather conditions. The inadvisability of excessive cultivation is very apparent.

TABLE 11.—Effects of the Number of Cultivations Upon the Yield of Cabbage

No. of fields	No. of cultivations and yields in tons per acre	Differences in yields, their probable errors, and odds		
		3 or less	4 to 6	More than 6
49	3 or less 9.32±0.29		0.46±0.32 (2 to 1)	1.41±0.40 (40 to 1)
223	4 to 6 8.86±0.14	0.46±0.32 (2 to 1)		0.95±0.31 (27 to 1)
34	More than 6 7.91±0.28	1.41±0.40 (40 to 1)	0.95±0.31 (27 to 1)	

Depth of cultivation.—The fields were grouped as to whether they were cultivated shallow, medium deep, or deep. By shallow, a depth of 1½ inches is inferred; by medium, 2½ inches; and by deep, 3½ inches.

TABLE 12.—Effects of Depth of Cultivation on the Yield of Cabbage

No. of fields	Depth of cultivation and yields in tons per acre	Differences in yields, their probable errors, and odds		
		Shallow	Medium	Deep
77	Shallow 9.11±0.23		0.21±0.27 (.....)	1.01±0.34 (22 to 1)
175	Medium 8.90±0.15	0.21±0.27 (.....)		0.80±0.29 (15 to 1)
54	Deep 8.10±0.25	1.01±0.34 (22 to 1)	0.80±0.29 (15 to 1)	

The data seem to indicate the detrimental effects of deep cultivation, bearing out the observations of Thompson (19).

Percentage of perfect stand.—The fields were classified as to whether the stand of plants in the field was 95 per cent perfect or better, between 85 and 95 per cent, or less than 85 per cent.

TABLE 13.—Effects of Stand on the Yield of Cabbage

No. of fields	Percentage stand and yield in tons per acre	Differences in yields, their probable errors, and odds		
		95 or better	Between 85 and 95	Less than 85
143	95 or better 9.74±0.15		1.49±0.23 (1350 to 1)	2.94±0.29 (1350 to 1)
108	Between 85 and 95 8.25±0.18	1.49±0.23 (1350 to 1)		1.45±0.31 (500 to 1)
55	Less than 85 6.80±0.25	2.94±0.29 (1350 to 1)	1.45±0.31 (500 to 1)	

It is quite evident that the stand of plants in a field has a very important influence on the yield.

A situation exemplifying this occurred at the Sandusky fertilizer test plots. The plants used for setting these plots were given an application of sodium nitrate in the seedbed. Although plants were twice reset in these plots, a very poor stand of plants resulted. The plants were large, vigorous, and succulent, presenting a fine appearance in the seedbed, but were too tender to withstand being transplanted successfully.

Weediness.—The prevalence of weeds in the field was used as a basis of a classification of the data. Fields were grouped as to whether they were free of weeds, fairly free, or weedy at harvest time.

The presence of weeds in the field lowered the yield of cabbage.

Nutritional.—Records were secured as to the amount of manure applied to each cabbage field, the amount and kind of fertilizer applied, and the method of applying the fertilizer. Statistical analysis revealed that for this set of data the amount and kind of fertilizer did not influence the yield of cabbage. As a matter of fact, when 10 or more tons of manure were applied per acre the average yield was less than when none was applied. Taking into account the drouthy climatological conditions which obtained and the denitrifying influence of material high in cellulose, these results are not very surprising. Young (25) also made the same observation the previous year. The fact that varying fertilizer applications were not influential also corroborates Young's results. Since it is a matter of common observation that fertilizers are more beneficial during wet seasons than dry ones, the results secured are not amiss when one takes into account the weather conditions which existed.

TABLE 14.—Effects of the Presence of Weeds on the Yield of Cabbage

No. of fields	Weediness and yields in tons per acre	Differences in yields, their probable errors, and odds		
		Free	Fairly free	Weedy
104	Free..... 9.77±0.21.....		0.99±0.26 (100 to 1)	2.58±0.33 (1350 to 1)
157	Fairly free..... 8.78±0.15.....	0.99±0.26 (100 to 1)		1.59±0.29 (1350 to 1)
45	Weedy..... 7.19±0.25.....	2.58±0.33 (1350 to 1)	1.59±0.29 (1350 to 1)	

FERTILIZER TEST PLOTS

Plots on Hampshire Farm at Fremont, Ohio.—The soil, a brownish-gray sandy loam, gave a reaction of pH 6.0 to 6.5. The nitrate test indicated the presence of 20 to 25 parts per million, and the phosphate test indicated that the amount of phosphate present was low. These and the following tests on the soil of the fertilizer test plots were made at the time the plants were set in the field.

The uniform yields of the checks in this series of plots, as shown in Table 15 and Figure 2, are striking and make the results secured from the other plots the more valuable. Inasmuch as each set of figures points towards the same conclusions, it matters little whether the results are considered with respect to the relative yield, the average weight per head, the actual total yield, or the

increase over the calculated check. Superphosphate appeared to be most effective in increasing the yield of cabbage, potash the least, and nitrate intermediate between the former two. The substitution of ammonium sulfate for sodium nitrate resulted in a reduced yield. The drilling of one-fourth of the fertilizer in the row caused an increase in yield. Side-dressings of sodium nitrate, 3 and 5 weeks after the plants were set, increased the yield. The fact that the average weight per head of the minus phosphorus plot was approximately the same as the corresponding figure for the check plots (although the average weight per head of all other treatments was consistently greater than that for the checks) is of some significance in indicating the important role of phosphorus in the nutrition of cabbage.

TABLE 15.—Yield of Cabbage—Hampshire Plots

Plot No.	Treatment	Weight, cut early	Average weight	Yield	Calculated check	Increase over calculated check
		Tons per acre	*Lb. per head*	*Tons per acre*	*Tons per acre*	*Tons per acre*
1	Check—no treatment.....	3.52	1.74	8.67	.....	.....
2	—N 1000 lb. 0-10-6 per acre.....	6.20	2.00	10.84	8.67	2.17
3	—P 1000 lb. 4-0-6 per acre.....	5.07	1.74	9.60	8.67	0.93
4	—K 1000 lb. 4-10-0 per acre.....	7.20	2.22	12.23	8.67	3.56
5	Complete 1000 lb. 4-10-6 per acre.	8.72	2.31	13.17	8.67	4.50
6	Check—no treatment.....	4.04	1.62	8.67	.....	.....
7	1000 lb. 4-10-6, ½ of N from nitrate, other ½ from ammonia..	7.40	2.09	11.15	8.68	2.47
8	Same as No. 7, but ¼ in row, ¾ broadcast.....	8.77	2.18	12.49	8.69	3.80
9	Same as No. 7, plus 150 lb. nitrate top-dressed at 3 and 5 weeks after setting	10.16	2.31	12.96	8.69	4.27
10	Check—no treatment.....	3.83	1.67	8.70	.....	.....

Plots on Diehr Farm at Fremont, Ohio.—This series of plots was in the same district as those previously mentioned. The soil is quite similar. It is also a brownish-gray sandy loam but with a reaction of pH 6.5 to 6.8. According to tests, it contained 15 to 20 parts per million of nitrates and gave a low reaction for phosphates.

As shown by Table 16, this series of plots produced results very comparable to the preceding ones. In this case, nitrogen had less influence and potash had more influence upon the yield of cabbage, in comparison with the plots at the Hampshire Farm. The side-dressing of sodium nitrate actually appeared detrimental on this soil. It is noticeable that the soil of the Diehr plots gave a lower nitrate test than that on the Hampshire Farm. At first thought it would seem that the application of nitrate should have been more beneficial on the Diehr plots than on the ones at the Hampshire Farm. Since the nitrate test was made during the middle of June, it indicates in no way the potentialities for further nitrification in these respective soils. Fertilizer applications not only increased the actual amount of cabbage harvested at the first cutting but also increased the amount cut in relation to the total yield of the respective plots.

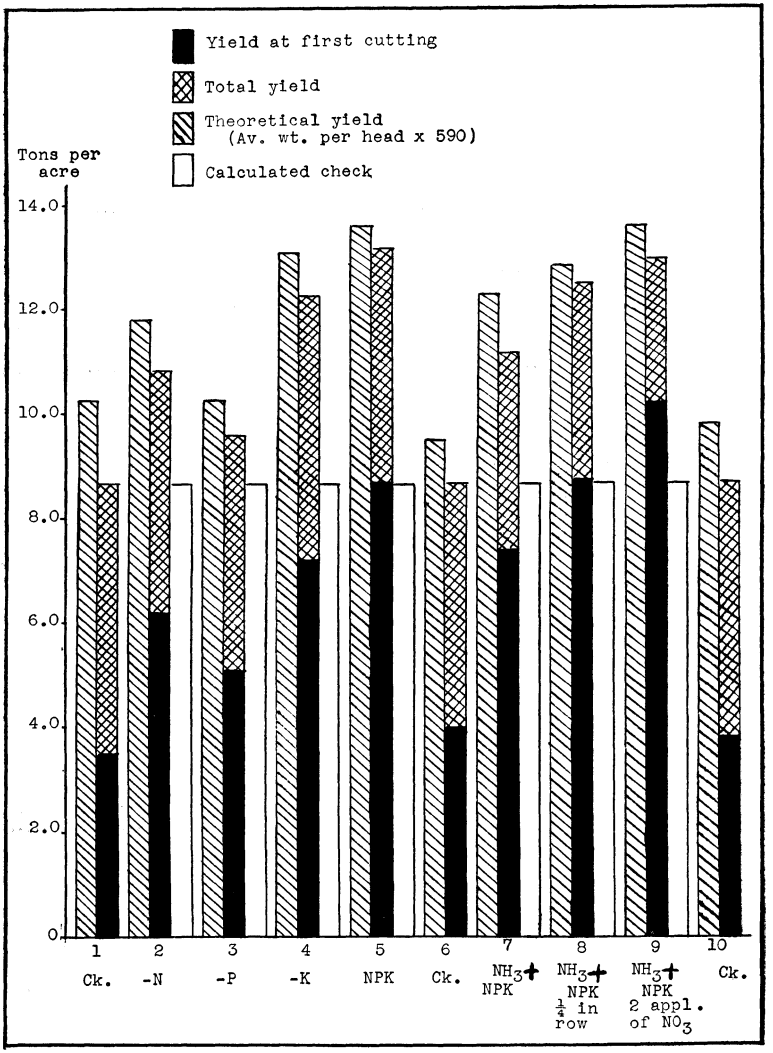

Fig. 2.—Yield of cabbage on the Hampshire plots

Plots at Sandusky, Ohio.—The soil on which these plots were located was a dark gray silty clay loam with a reaction of pH 6.5-6.8. The nitrate test indicated the presence of 10 to 15 parts per million, and the phosphate test gave a medium reaction.

The figures presented in Table 17 show that the results of these plots were of questionable value. The stand of plants in these plots was quite poor. As previously mentioned, the plants used to set these plots had received an application of sodium nitrate in the seedbed and were too succulent to withstand being transplanted successfully. Plots 2, 3, and 4 produced results which were more or less in agreement with the previously mentioned ones—phosphate

TABLE 16.—Yield of Cabbage—Diehr Plots

Plot No.	Treatment	Weight, cut early	Average weight	Yield	Calculated check	Increase over calculated check
		Tons per acre	*Lb. per head*	*Tons per acre*	*Tons per acre*	*Tons per acre*
1	Check—no treatment.....	3.48	1.46	7.02	.....	.....
2	—N 1000 lb. 0-10-6 per acre.....	7.19	1.94	10.96	7.33	3.63
3	—P 1000 lb. 4-0-6 per acre.....	6.37	1.83	10.37	7.66	2.71
4	—K 1000 lb. 4-10-0 per acre.....	7.19	1.92	10.95	7.99	2.96
5	Complete 1000 lb. 4-10-6 per acre	9.67	2.20	12.99	8.32	4.67
6	Check—no treatment	3.24	1.64	8.64	.....	.....
7	1000 lb. 4-10-6, ½ of N from nitrate, other ½ from ammonia.	8.17	2.12	12.29	8.63	3.66
8	Same as No. 7, but ¼ in row, ¾ broadcast.....	7.50	2.16	12.40	8.62	3.78
9	Same as No. 7, plus 150 lb. nitrate top-dressed at 3 and 5 weeks after setting.....	7.98	2.12	11.78	8.61	3.17
10	Check—no treatment.....	3.99	1.63	8.59	.....	.....

TABLE 17.—Yield of Cabbage—Sandusky Plots

Plot No.	Treatment	Weight, cut early	Average weight	Yield	Calculated check	Increase over calculated check
		Tons per acre	*Lb. per head*	*Tons per acre*	*Tons per acre*	*Tons per acre*
1	Check—no treatment.....	4.40	1.97	5.80	.....	.....
2	—N 1000 lb. 0-10-6 per acre.....	6.10	1.98	7.90	5.84	2.06
3	—P 1000 lb. 4-0-6 per acre.....	2.90	1.89	7.10	5.88	1.22
4	—K 1000 lb. 4-10-0 per acre.....	4.50	2.13	8.40	5.92	2.48
5	Complete 1000 lb. 4-10-6 per acre	4.70	1.99	7.90	5.96	1.94
6	Check—no treatment	3.30	1.66	6.00	.....	.....
7	1000 lb. 4-10-6, ½ of N from nitrate, other ½ from ammonia .	2.50	1.55	4.30	5.15	—0.85
8	Same as No. 7, but ¼ in row, ¾ broadcast.....	2.90	1.60	4.00	4.30	—0.30
9	Same as No. 7, plus 150 lb. nitrate top-dressed at 3 and 5 weeks after setting.....	2.30	1.40	3.40	3.45	—0.05
10	Check—no treatment.....	1.50	1.11	2.60	.....	.....

being most effective, potash least, and nitrogen intermediate in increasing the yield over the checks. Plots 7, 8, and 9 produced such poor results that it is questionable if they present a true picture of the potentialities of the respective treatments.

Plots at Clyde, Ohio.—These plots were located on a yellow sand with a reaction of pH 6.3 to 6.7. It contained about 15 to 20 parts per million of nitrates and a medium amount of available phosphate at the time of transplanting.

As indicated by Table 18, the variation existing among the various treatments is rather small, possibly due to the fact that moisture was more of a limiting factor than nutrients. As shown by the figures for the increase in yield over the calculated checks, nitrogen was the most influential and potash the least influential in increasing the yield, but the differences were so slight they hardly merit comparison. The average weight per head of the cabbages harvested from the respective plots is so inconsistent with the total yields that the significance of the results is almost completely masked.

TABLE 18.—Yield of Cabbage—Clyde Plots

Plot No.	Treatment	Weight, cut early	Average weight	Yield	Calculated check	Increase over calculated check
		Tons per acre	*Lb. per head*	*Tons per acre*	*Tons per acre*	*Tons per acre*
1	Check—no treatment	1.33	1.88	6.66	.....	.....
2	—N 1000 lb. 0-10-6 per acre	1.70	1.84	6.93	6.13	0.80
3	—P 1000 lb. 4-0-6 per acre	2.43	1.96	7.16	6.21	0.95
4	—K 1000 lb. 4-10-0 per acre	3.31	1.84	7.32	6.29	1.03
5	Complete 1000 lb. 4-10-6 per acre.	3.10	1.88	7.71	6.37	1.34
6	Check—no treatment	2.24	1.73	6.43	.....	.....
7	1000 lb. 4-10-6, ½ of N from nitrate, other ½ from ammonia	2.02	1.83	7.10	6.40	0.70
8	Same as No. 7, but ¼ in row, ¾ broadcast	2.34	1.77	7.26	6.37	0.89
9	Same as No. 7, plus 150 lb. nitrate top-dressed at 3 and 5 weeks after setting	3.10	1.77	7.39	6.34	1.05
10	Check—no treatment	2.19	1.62	6.31	.....	.....

Plots at Erlin, Ohio.—This series of plots was located on a dark gray silt loam soil with a reaction of pH 7.2 to 7.4. At the time of setting the plants, this soil tested 15 to 20 parts per million of nitrate nitrogen and a medium content of available phosphorus.

It would seem that the results of these plots are quite inconsistent with the results of the other plots. This is true, but it is also evident that this series of plots was the only one on a soil having a pH value above 7.0. In the light of the data presented by Tiedjens and Robbins (21) and Naftel (15), the results of this series of plots are quite in accord with what might be expected. The noticeably high average weight per head of the cabbages harvested from Check Plot 1 would tend to indicate that the soil variability exerted some influence on the results.

According to the results of the Erlin plots, the use of ammoniacal fertilizers as a source of nitrogen for cabbage on alkaline soil would appear advantageous.

TABLE 19.—Yield of Cabbage—Erlin Plots

Plot No.	Treatment	Weight, cut early	Average weight	Yield	Calculated check	Increase over calculated check
		Tons per acre	*Lb. per head*	*Tons per acre*	*Tons per acre*	*Tons per acre*
1	Check—no treatment	.....	2.98	12.10	.....	.....
2	—N 1000 lb. 0-10-6 per acre	.....	2.65	11.40	12.01	—0.61
3	—P 1000 lb. 4-0-6 per acre	1.78	2.13	11.44	11.92	—0.48
4	—K 1000 lb. 4-10-0 per acre	2.23	2.61	11.48	11.83	—0.35
5	Complete 1000 lb. 4-10-6 per acre.	2.23	2.53	10.93	11.74	—0.81
6	Check—no treatment	2.79	2.49	11.64	.....	.....
7	1000 lb. 4-10-6, ½ N from nitrate, other ½ from ammonia	2.77	2.70	13.44	11.43	2.01
8	Same as No. 7, but ¼ in row, ¾ broadcast	4.78	2.79	14.46	11.22	3.24
9	Same as No. 7, plus 150 lb. of nitrate top-dressed at 3 and 5 weeks after setting	4.49	2.78	14.39	11.01	3.38
10	Check—no treatment	1.43	2.50	11.01	.....	.....

Plots at Celina, Ohio.—The soil was a dark gray, heavy silt loam with an acidity of pH 6 to 6.5, a nitrate nitrogen test of 15 to 20 parts per million, and a medium test for phosphate.

The main object of this series was to determine the effect of various applications of nitrogen on the yield of cabbage. It appears that as the amount of nitrogen applied was increased on Plots 9, 10, 11, and 12, the yield correspondingly decreased. Also, the yield correspondingly decreased the later the top-dressing of nitrate was applied on Plots 2, 3, 4, and 5. The potash- and phosphorus-deficient plots showed the smallest increase over the checks. Applications of nitrogenous fertilizer to this soil under climatic conditions existing during the summer of 1931 were not profitable.

Plots at Green Springs, Ohio.—These plots were located on a gray-black loamy sand with an acidity of pH 6.8, a nitrate nitrogen test of 25 to 30 parts per million, and a medium test for phosphate. The differences in yield were so slight that the most logical conclusion would be that fertilizers were of no benefit to this soil. A cover crop of sweet clover was plowed under in addition to an application of 8 tons of manure per acre. The nitrate test which was made previous to the application of any fertilizer showed that the nitrate content of the soil was entirely sufficient for the growth of cabbage. It is of interest to note that Plot 2, receiving only potash and phosphate, produced the highest yield. Tests on the effect of the physiological condition of the cabbage on the resultant kraut are given subsequently.

Kraut was made from different lots of cabbage which had matured as described in Table 22, in order to secure information concerning the quality of kraut that could be made from cabbage that had been grown under different adverse, as well as under favorable, conditions.

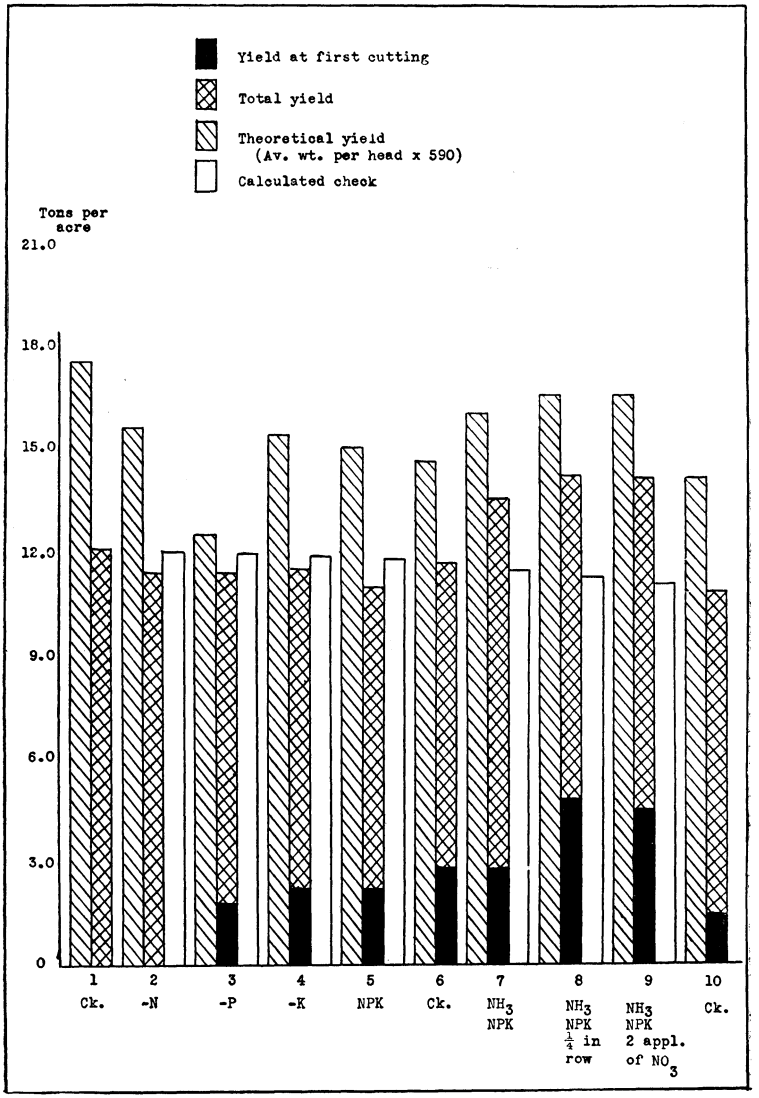

Fig. 3.—Yield of cabbage on the Erlin plots

TABLE 20.—Yield of Cabbage—Celina Plots

Plot No.	Treatment	Weight, cut early	Average weight	Yield	Calculated check	Increase over calculated check
		Tons per acre	*Lb. per head*	*Tons per acre*	*Tons per acre*	*Tons per acre*
1	Check—no treatment	3.01	2.24	13.52	.....	.....
2	1000 lb. of 4-10-6, plus surface application of N early	12.59	3.10	18.59	13.30	5.29
3	1000 lb. of 4-10-6, plus surface application of N late	11.67	2.88	17.14	13.10	4.04
4	1000 lb. of 4-10-6, plus surface application of N very late	7.64	2.70	15.78	12.90	2.88
5	1000 lb. of 4-10-6, plus surface application of N early and late	7.29	2.87	16.71	12.70	4.01
6	—K 1000 lb. 4-10-0	6.46	2.63	15.16	12.50	2.66
7	Check—no treatment	2.12	2.39	12.29	.....	.....
8	Check—no treatment	5.17	2.30	14.09	.....	.....
9	No nitrogen, 1000 lb. 0-10-6	13.79	2.98	18.01	13.77	4.24
10	Light application of N 1000 lb. 2-10-6	12.21	2.93	17.51	13.44	4.07
11	Medium application of N 1000 lb. 4-10-6	10.32	2.92	17.21	13.11	4.10
12	Heavy application of N 1000 lb. 8-10-6	8.26	2.91	16.60	12.78	3.82
13	—P 1000 lb. 4-0-6	5.42	2.69	15.21	12.44	2.77
14	Check—no treatment	2.92	2.38	12.11	.....	.....

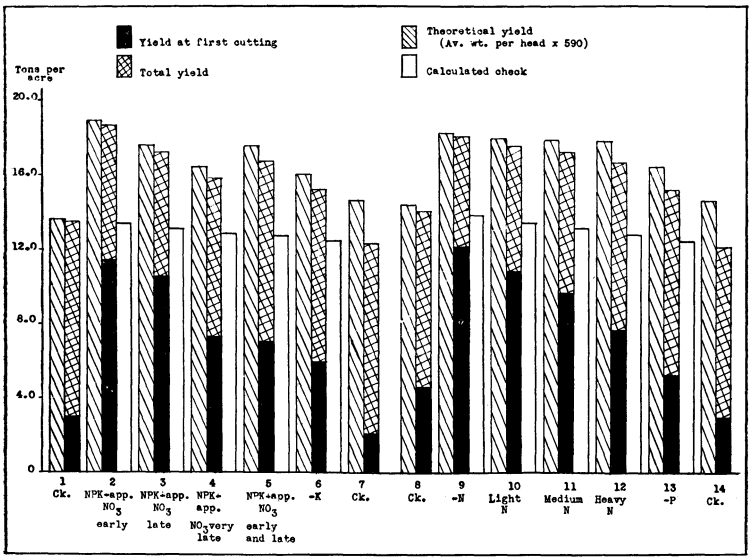

Fig. 4.—Yield of cabbage on the Celina plots.

TABLE 21.—Yield of Cabbage—Green Springs Plots

Plot No.	Treatment	Average weight	Yield	Calculated check	Increase over calculated check
		Lb. per head	*Tons per acre*	*Tons per acre*	*Tons per acre*
1	Check—no treatment	2.15	10.80	.....	.....
2	No N, 1000 lb. 0–10–6 per acre	2.41	12.50	10.68	1.82
3	Light application of N, 1000 lb. 2–10–6	2.20	10.90	10.56	0.34
4	Medium application of N, 1000 lb. 4–10–6	2.31	10.90	10.44	0.46
5	Heavy application of N, 1000 lb. 8–10–6	2.36	10.70	10.32	0.38
6	1000 lb. 4–10–6, plus surface application of N early	2.38	11.00	10.20	0.80
7	1000 lb. 4–10–6, plus surface application of N late	2.35	11.30	10.08	1.22
8	1000 lb. 4–10–6, plus surface application of N very late	2.15	10.90	9.96	0.94
9	1000 lb. 4–10–6, plus surface application of N early and late	2.39	11.60	9.83	1.77
10	Check—no treatment	1.95	9.70	.....	.....

TABLE 22.—Description of Cabbage Samples Secured

No.	Locality where grown	Type of soil	Size of cabbage (average)	Description of cabbage	Keeping quality
1	Celina	Silt loam high in nitrates	Large	Solid, from vigorously growing plants	Fair
2	Bellevue	Silt loam highly limed	Very small	Solid, appeared stunted from excess of lime locking up P	Good
3	Bellevue	Muck not fertilized	Very small	Fairly solid, showed symptoms of P and K starvation	Very poor
4	Bellevue	Muck fertilized	Very large	Solid, from very vigorous plants	Good
5	Clyde	Light sand	Small	Very solid, showed symptoms of N starvation	Very good
6	Fremont	Dark sandy loam	Very small	Solid, stunted from phosphorus starvation	Good
7	Fremont	Silt loam highly limed	Medium	Fairly solid plants, appeared stunted from an excess of lime	Fair
8	Liberty Center	Dark sand	Small	Fairly solid, showed marked symptoms of K starvation	Poor

The cabbage showing symptoms of potassium starvation kept the poorest in cold storage, while that which showed symptoms of nitrogen starvation kept the best. Kimbrough (9) noted that cabbage plants which received nitrate of soda and superphosphate but no potash became affected with a physiological disease and produced poor quality cabbage. An excess of available nitrogen in comparison with the other necessary elements tends to produce cabbage with very succulent tissue which breaks down comparatively rapidly during storage.

TABLE 23.—Sugar Analysis of Cabbage Samples Secured

Sample No.	Per cent of green weight		
	Reducing sugars	Inverted sugar	Total sugar
1	3.312	0.812	4.124
2	3.323	0.953	4.276
3	2.518	0.549	3.067
4	3.584	0.869	4.453
5	3.665	1.647	5.312
6	3.224	1.403	4.627
7	3.314	0.762	4.076
8	2.702	1.016	3.718

These results are in accordance with the evidence that sugars tend to accumulate under conditions of inhibited nitrogen metabolism; whereas conditions favoring nitrogen metabolism tend to prevent or retard a significant accumulation of sugars, especially disaccharides.

TABLE 24.—Description of Sauerkraut Made from Cabbage Samples

No.	Salometer reading	Acidity calculated as lactic	Color	Flavor	Texture	Quality
	Degrees	*Per cent*				
1	20.0	1.56	Medium dark	Fair	Somewhat tough	Fair
2	19.0	1.51	Quite yellow	Acrid	Firm	Good
3	20.0	1.39	Very dark	Bitter	Soft	Very poor
4	18.5	1.56	Light	Good	Firm	Very good
5	19.0	1.62	Very light	Good	Crisp	Very good
6	19.5	1.68	Fairly light	Fair	Fairly crisp	Fair
7	19.0	1.65	Fairly light	Good	Firm	Good
8	19.5	1.60	Dark	Poor, bitter	Fairly crisp	Poor

A study of the data in Tables 23 and 24 points towards the fact that there is a correlation between the keeping quality of cabbage and its value for kraut. It appears that there is a possibility of potash deficiency in the cabbage field being partly responsible for inferior quality of the kraut made from such cabbage. An excess of available nitrogen in the cabbage also seems to have undesirable effects on the quality of kraut.

DISCUSSION OF RESULTS

To illustrate better the significance of the survey data a chart (Fig. 5) was prepared. The bars in Figure 5 represent the maximum quotient of the difference divided by the error for the factors designated in the data presented in the different tables. This chart indicates that proper attention to the soil management program in the cabbage field is more important than the application of fertilizers.

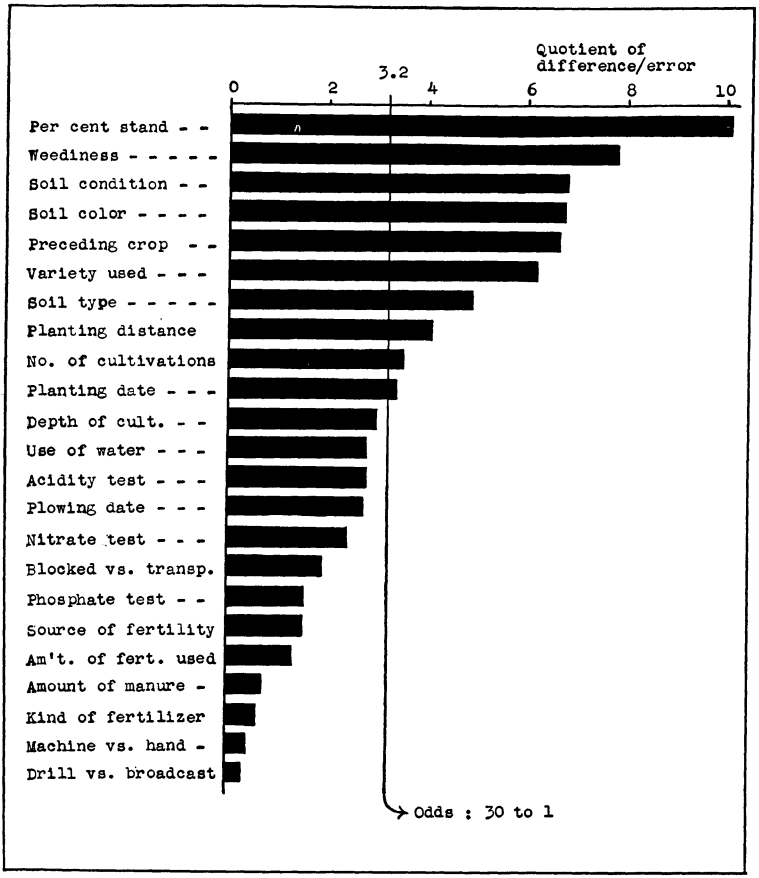

Fig. 5.—Maximum quotient of difference / error for factors designated. Arrangement of factors in descending order

Figure 6 is a chart of the average of the results secured from the Hampshire, Diehr, Sandusky, Clyde, and Erlin Plots. It is conceded that this procedure is subject to criticism because of the soil variations involved. Nevertheless, a glance at this chart will reveal that it portrays the response of cabbage to the fertilizer components with a relationship which in no small way corresponds to the results secured at Marietta, Ohio, and State College, Pennsylvania, for quite a long period of years.

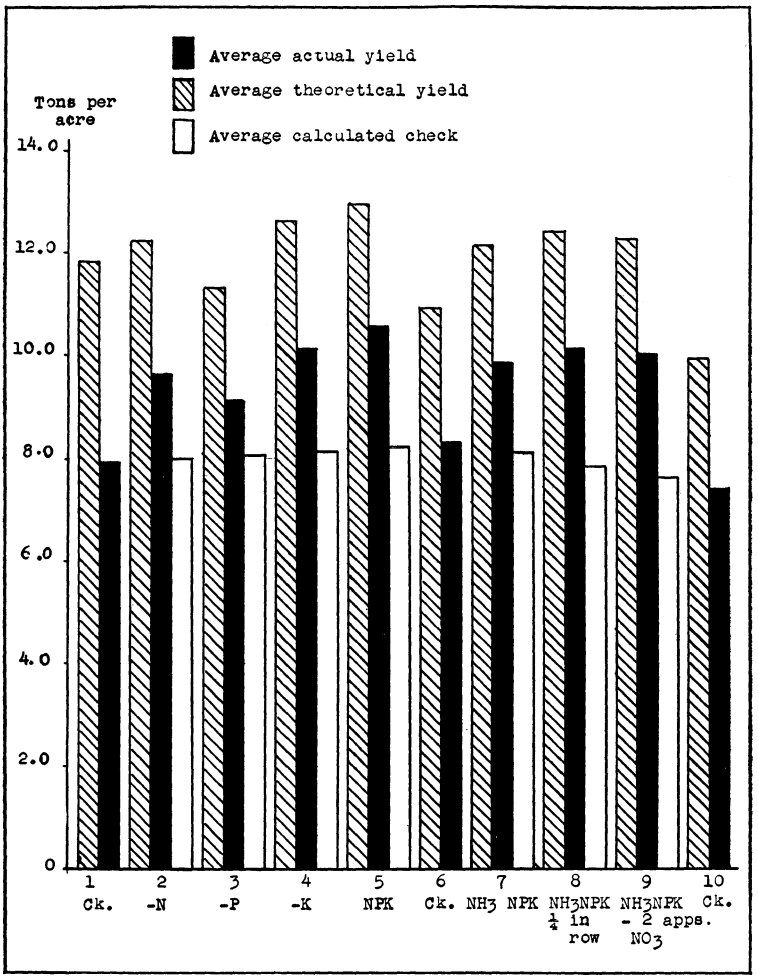

Fig. 6.—An average of the results secured from the fertilizer plots

The significance of the response of cabbage to fertilizer on these various plots was computed by "Student's" method and is presented diagrammatically in Figure 7. Similar treatments from each series of plots were grouped and compared with another group of similarly treated plots. The most significant difference occurred when plots receiving phosphorus and one other fertilizer component were compared with their calculated checks. The least significance was associated with the comparison between plots receiving a complete fertilizer and those receiving a complete fertilizer minus either potassium or nitrogen. Plots having all their nitrogen in the form of nitrate were superior in production to those receiving half of their nitrogen in the form of ammonia. An application of part of the fertilizer in the row was accompanied by a significant increase in yield. Applying nitrate 3 and 5 weeks after the plants were set in the field did not cause a significant increase in yield.

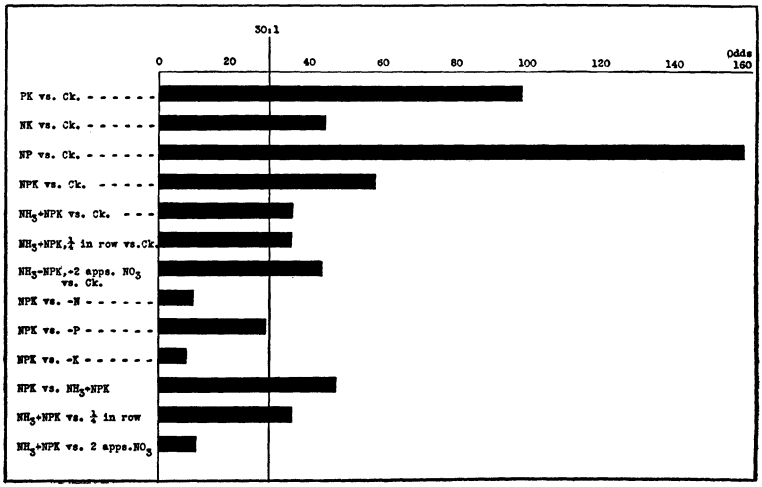

Fig. 7.—Significance of the results secured from the combined fertilizer plots as computed by "Student's" method

SUMMARY

The climatic conditions existing during the summer of 1931 were only fairly conducive to the growth of cabbage. The extremely dry and hot weather which existed during July doubtless exerted a modifying influence on the yields of cabbage.

Cabbage yielded best on sandy loam soils and poorest on clay loam soils. Loams produced intermediate yields.

The yield of cabbage was highest on the black soils. The yield decreased with the lighter colored soils, being lowest on the lightest colored soils.

The acidity of the soil did not significantly influence the yield of cabbage.

A moderately high nitrate nitrogen content of the soil, as determined by the diphenylamine test, exerted a favorable influence on the yield of cabbage.

There was no correlation between the Bray test for available soil phosphorus and the yield of cabbage.

The yield of cabbage was influenced by the preceding crop. Cabbage grew better following cultivated crops than following uncultivated ones. However, a preceding crop of clover was found to be the most favorable.

Cabbage is very sensitive to the condition of the soil at transplanting time.

The date of plowing the field for cabbage did not exert a significant influence upon the yield.

Cabbage which had been transplanted tended to yield better than that which had been seeded in the row and blocked.

Cabbage which had been transplanted to the field before June 15 yielded better than that which was transplanted after that date.

Cabbage yields appeared to be affected by the planting distance. Crowding the plants or setting them too far apart reduced the yield. Plants set 23 to 28 inches apart in rows 30 to 33 inches apart appeared to give the best results.

There was no difference in the yields of cabbage as affected by either hand or machine transplanting.

The necessity of the use of water in the transplanting machine was found to be influenced by weather conditions. Water proved to be beneficial only when the weather was dry and hot.

The yield of cabbage was greatly lowered by the use of varieties susceptible to yellows.

The yield of cabbage varied inversely with the number of times it was cultivated.

The yield of cabbage tended to vary inversely with the depth of cultivation.

The yield of cabbage was greatly influenced by the percentage of perfect stand. The fields having the poorer stands had decidedly inferior yields.

The yield of cabbage varied inversely with the weediness of the field.

Cabbage made no response to applications of manure.

A combination of manure and fertilizer did not influence the yield of cabbage as compared with fertilizer alone, manure alone, or neither.

The yield of cabbage tended to increase with increasing fertilizer applications but the increase was not significant.

The survey data indicate that the kind of fertilizer used had no influence on the yield of cabbage.

The method of applying the fertilizer did not affect the yield of cabbage according to the survey.

On the fertilizer test plots, cabbage was found to be most responsive to phosphorus, least to potassium, and intermediately to nitrogen.

Certain of the test plots tended to indicate that the yield of cabbage may be impaired by an excess of nitrate nitrogen in the soil.

The test plots produced results which would lend weight to the hypothesis that under alkaline soil conditions cabbage utilizes ammonia nitrogen much better than nitrate nitrogen, with a reverse situation under acid soil conditions.

Some evidence was found which would substantiate the view that environmental conditions which hinder the accumulation of sugars in the cabbage also impair its keeping in storage.

Cabbage which has a low sugar content or which was grown in a seriously unbalanced nutritional environment made an inferior quality of sauerkraut. A deficiency of potassium accompanied by a sufficiency of nitrogen appeared to be particularly detrimental to the quality of kraut cabbage.

ACKNOWLEDGMENTS

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LITERATURE CITED

1. Bray, R. H. 1929. A field test for available phosphorus in soils. Ill. Agr. Exp. Sta. Bull. 337.

2. Burrell, R. C. 1932. Methods in Phytochemical Research. (Mimeograph.)

3. Comin, D. and J. Bushnell. 1928. Fertilizers for early cabbage, tomatoes, cucumbers, and sweet corn. Ohio Agr. Exp. Sta. Bull. 420.

4. Fite, A. B. 1926. Growing early cabbage. N. Mex. Agr. Exp. Sta. Bull. 151.

5. ————. 1930. Cabbage fertilizer experiment. N. Mex. Agr. Exp. Sta. Bull. 180.

6. Jones, H. A. 1928. Cabbage production in California. Calif. Agr. Exp. Sta. Circ. 262.

7. ———— and J. T. Rosa. 1928. Truck crop plants. McGraw-Hill Book Co., New York.

8. Jones, L. R., J. Johnson, and J. G. Dickson. 1926. Wisconsin studies upon the relation of soil temperature to plant diseases. Wisc. Agr. Exp. Sta. Res. Bull. 71.

9. Kimbrough, W. D. 1928. Effect of fertilization on the quality of vegetables. Ala. Agr. Exp. Sta. Report.

10. LeFevre, E. 1928. A commercial production of sauerkraut. U. S. D. A. Circ. 35.

11. Love, H. H. 1924. A modification of "Student's" table for use in interpreting experimental results. Jour. Amer. Soc. Agron. **16**: 68-73.

12. Mack, W. B. 1927. Fertilization of truck crops. Pa. Agr. Exp. Sta. Bull. 210.

13. ————. 1928. Early cabbage. Pa. Agr. Exp. Sta. Bull. 221.

14. Morgan, M. F. 1930. A simple spot plate test for nitrate nitrogen in soil and other extracts. Science **LXXI**: 343-344.

15. Naftel, J. A. 1931. The absorption of ammonium and nitrate nitrogen by various plants at different stages of growth. Jour. Amer. Soc. Agron. **23**: 142-158.

16. Shaffer, P. A. and A. F. Hartmann. 1920. The iodometric-determination of copper and its use in sugar analysis. Jour. Biol. Chem. **45**: 349-390.

17. Sinnott, E. W. and L. C. Dunn. 1925. Principles of Genetics. McGraw-Hill Book Co., New York.

18. Thompson, H. C. 1923. Vegetable Crops. McGraw-Hill Book Co., New York.

19. ————. 1927. Experimental studies of cultivation of certain vegetable crops. Cornell Univ. Agr. Exp. Sta. Memoir 107.

20. ————, P. H. Wessels, and H. S. Mills. 1931. Cultivation experiments with certain vegetable crops on Long Island. N. Y. (Cornell) Agr. Exp. Sta. Bull. 521.

21. Tiedjens, V. A. and W. R. Robbins. 1931. The use of ammonia and nitrate nitrogen by certain crop plants. N. J. Agr. Exp. Sta. Bull. 526.

22. Ware, L. M. 1930. Fertilizer work with cabbage. Miss. Agr. Exp. Sta. Cir. 91.

23. Wood, T. B. 1911. The interpretation of experimental results. Jour. Bd. Agr., London Suppl., 7: 15-37.

24. Worthen, E. L. 1927. Farm soils. John Wiley & Sons, Inc., New York.

25. Young, R. E. 1930. The effect of fertilizer and cultural practices on the yield and quality of kraut cabbage. Thesis, The Ohio State University.

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